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The state of the art of small-scale pellet-based heating systems and relevant regulations in Sweden, Austria and Germany

Frank Fiedler *

Solar Energy Research Center SERC, Department of Mathematics, Natural Sciences and Technology, Dalarna University College, S-7188 Borlänge, Sweden

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Abstract

The emphasis of this report is on the actual technology of small-scale pellet combustion units and important regulations concerning emissions and pellets. Wood as a heating source has a long tradition in Sweden, but the use of compressed wood pellets in domestic stoves and boilers is rather new. Based on a literature survey, information from manufacturers and test institutes, this report gives an overview about existing technology and investigates how mature it is already. Some comparisons were made to similar heating units in Austria, where this technique is also widely used. It could be seen that the Austrian boilers are more sophisticated including a high level of comfort for the user. On the other hand the simpler Swedish boilers are significantly less expensive, and it is questionable if Swedish costumers are willing to pay for the higher comfort. Relevant regulations concerning emissions and fuel quality are also reported and compared between Sweden, Germany and Austria. In addition some interesting non-official certificates and environmental labels are presented. These give an outlook to future, probably more stringent, regulations.

Keywords: Pellet heating systems; Pellet boiler; Emission regulations; Pellet standards; Sweden; Austria; Germany

* Tel.: +46-23-77-87-11; fax: +46-23-77-87-01.
E-mail address: ffi@du.se (F. Fiedler).

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1. Introduction

In Sweden the biggest part of the one- and two-dwelling houses is heated by direct or water-based electricity heating systems (Fig. 1). Electricity is a high grade form of energy which unlike other energy forms, can easily be transformed to other kinds of energy. The use of electricity for low grade heating should therefore be reduced in Sweden, especially during the winter season when the electricity demand already exceeds the production. One solution is the application of carbon dioxide neutral pellet heating systems.

The majority of today's small-scale pellet heating systems are installed in Sweden and Austria, with a still rising tendency. In both countries this expansion is based on a long tradition of wood-based heating systems.

Both markets have been developed independently from each other so that the applied heating technology shows clear differences. In recent years the German market has also been growing enormously (Fig. 2).

That there is still a large potential for all three markets can be seen from Fig. 3. The highest capacity for pellet heating systems can be expected from the German market but even in Sweden, where the majority of systems have been installed so far, only every fiftieth one- or two dwelling houses is equipped with a pellet-based heating system.

The applied technology in Germany is in most cases imported from Austria. The reasons for this high growth rate seem to be different in each country. In Sweden

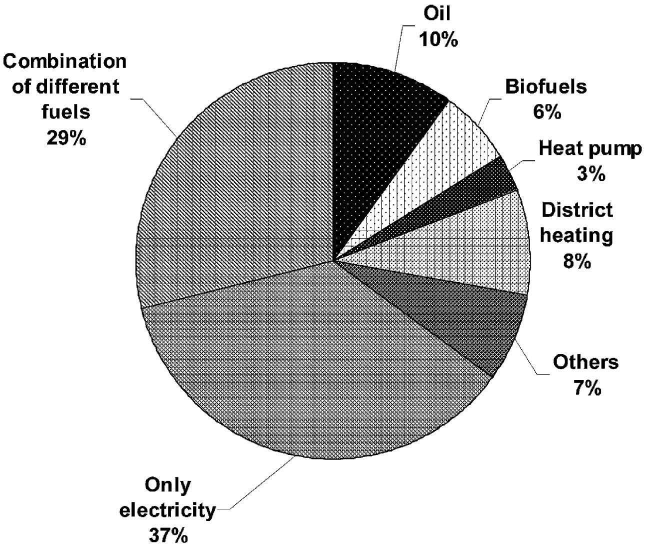


Fig. 1. Use of energy for heating of one- and two-dwelling houses in Sweden 2002 [1].

the tax policy on fuels promotes wood pellets and makes them significantly cheaper compared to oil and electricity. The relatively cheap investment costs for pellet heating system are another clear factor in favor of pellets. In Austria and Germany the price differences for fuels are less significant. But predictable rises in fuel prices and taxes, as well as the high technical standard of pellet heating systems, the

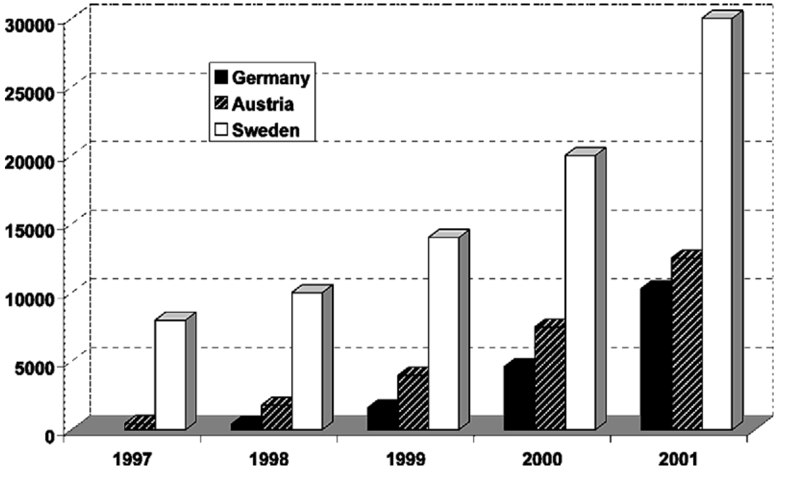


Fig. 2. Total number of installed pellets boiler and pellets heating stoves in one- or two-dwelling houses in Germany, Austria and Sweden [9,31,39].

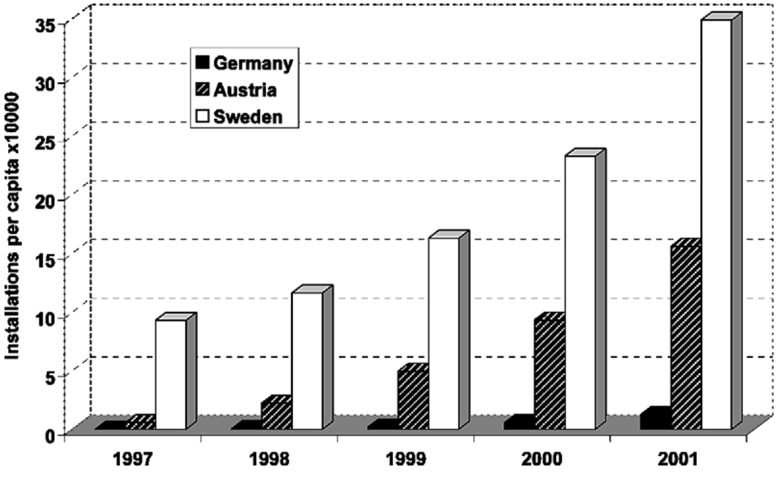


Fig. 3. Total number of installed pellet heating systems per capita times 1000 in one- or two-dwelling houses in Germany, Austria and Sweden [9,31,39].

environmental friendly image and direct governmental incentives seem to be sufficient motivation to invest in this technology [15].

Compared to conventional heating systems, such as oil or gas boilers, pellet heating technology still has disadvantages in terms of space demand, efficiency, emissions and maintenance. Intelligent design and sophisticated technology can minimize these disadvantages.

This paper will provide the reader with an overview of the actual technology used in pellet boilers and stoves. The difference in the system design between Sweden and Austria will be pointed out and an assessment on the level of the technology that has been reached will be given. Moreover future system improvements will be proposed.

The paper will also survey the important relevant regulations such as standards for emissions and the quality of pellets. Besides the official regulations custom-made certificates and labels are also investigated.

The investigations on pellet heating systems in Sweden, Austria and Germany are based on a literature survey. Information have been taken from scientific papers, conference presentations, books, manufacturers' instructions and reports from test institutes.

2. Combustion

In order to ensure complete pellet combustion with low emissions and low slagging, the quantity and method of supplying the combustion air is of extreme importance. To optimize the combustion it is necessary to divide the combustion chamber into a primary and a secondary combustion zone, where each zone has its own air supply. In the primary zone the primary combustions takes place which

consist of two phases, the drying phase, the pyrolyses and the final combustion. During drying the remaining water is released and evaporated from the pellets. Then the dry pellets will be decomposed in combustable, volatile components and char. The primary combustion requires energy input and takes place with an air ratio below the stochiometric ratio, i.e. with deficient air supply. During the secondary combustion the flammable gases are combusted in the secondary zone with excess air. Simultaneously the char is combusted in the primary combustion zone. During both oxidations, energy is released. In the primary combustion zone primary and secondary combustion take place at the same time, when unburned pellets are fed. For an optimized combustion a proper mixing of the secondary air with the flue gas is required. This can be achieved by geometry of the combustion chamber and the arrangement and design of the secondary air nozzles. The longer the flue gas stays in the furnace the more complete the combustion will be [10].

The amount of excess air in the secondary zone is not only of importance for carbon monoxide (CO) and unburnt hydrocarbons (OGC). There is a trade-off of between these emissions and the emission of nitrogen oxides (NOx). Too little air will result in increased emissions of CO and OGC, but will keep the amount of NOx in the flue gas small. With greater excess air, more NOx will be released from the burner. Measurements have shown that pellet burners often emit two to four times more NOx compared to oil burners. The pellet boiler and burner on the Swedish market are developed to be predominantly operated with high excess air [8]. A better control of the air supply by using a variable speed fan controlled by a CO or a lambda sensor would help to minimize the emissions. In Austrian and Germany pellet boilers with lambda control are already state of the art [26,27,28], whereas Swedish pellet heating devices often allow only a manual adjustment [12,13,29].

Another two important parameters for low carbon monoxide, unburnt hydrocarbons and nitrogen oxides are the residence time of the flue gas and the temperature in the combustion chamber. A high temperature and a long residence time reduce the emissions of CO and OGC to almost zero. The content of nitrogen oxides in the exhaust gas is increasing with increasing temperature unless a sufficient residence time is achieved. Consequent air staging in order to obtain high temperature and long residence times is a practical method to reduce emissions from pellet boilers [41].

3. Pellet heating technology

For the combustion of pellets two types of units can be found on the Swedish market:

- *Central heating boilers* (Fig. 4) are used to provide heat for single- or multi-family houses. The heat is transferred by an exhaust gas to water heat exchanger to the heat distribution system. The maximal heating power of these devices is in the range of 10 to 40 kW, where some are automatically modulating the power from 30 to 100% according to the heat demand.



Fig. 4. Left: Swedish pellet boiler Effecta-Pannan [13], Middle, right: Austrian pellet boiler ÖkoFen [24].

- *Stoves* (Fig. 5), which are used to heat single rooms, compact apartments or even a whole low energy house. The heat from the stove is transferred to the building by heat convection and radiation. Some stoves have additional water jackets and can be connected to a water-based radiator system. The heating power is maximal around 10 kW and can be regulated manually or automatically by the room temperature.

3.1. Boilers

Central pellet heating boilers are basically designed like conventional oil boilers. The fuel is transported from the store to the burner placed in the combustion

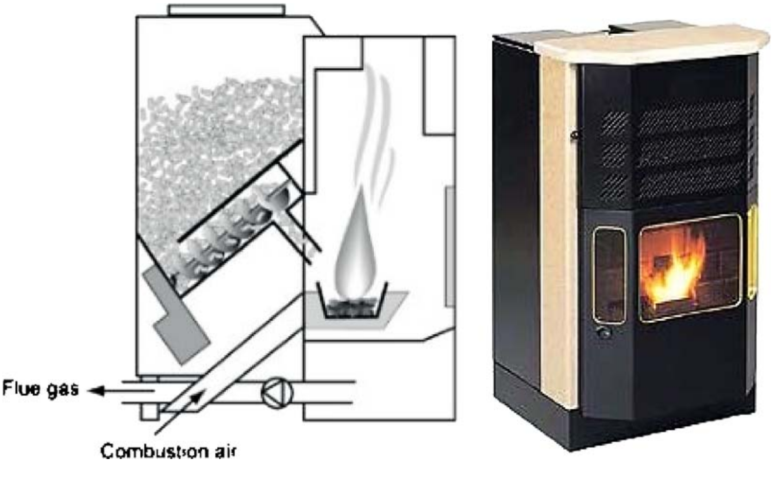


Fig. 5. Pellet heating stove with an integrated pellet store [9,12].

chamber, where the fuel will be lighted and combusted. The flue gas is conducted in several passages through the heat exchanger and transfers its energy to the water on the other side of the heat exchanger. A circulation pump transports the heated water to the heat distribution system. To improve the heat transfer and supply sufficient combustion air a fan is installed. The size of the combustion chamber and the heat exchanger need to be adapted to the maximum power of the burner to ensure consistent combustion and a sufficient heat transfer over the whole power range. The whole boiler is insulated and covered with sheet metal to prevent damage and reduce heat loss to the boiler location.

In Sweden two types of central heating boilers were identified:

- *Two unit boilers* are the most common boilers in Sweden [30]. This type of boiler is a combination of a pellet burner and a standard boiler (without burner) often produced by different manufacturers. The standard boiler can be combined with different types of burners. A common case is that an old oil boiler will be replaced with a pellet burner. This replacement is very easy to accomplish since the connection flange between boiler and burner is the same for oil and pellet burners. This simplicity is one reason for the high number of installed pellet heating systems in Sweden.
- *Integrated boilers* are rather uncommon on the Swedish market. Most systems of this type are imported, but a few are also manufactured in Sweden. In integrated boilers, as the name already says, the burner is part of the boiler and cannot be separated. The design of integrated pellet boilers is based on split log wood boilers. Some of these types of boiler also have an embedded pellet storage.

Unlike Sweden, integrated pellet boilers are the dominating type of pellet boiler in Austria and Germany [31]. Nevertheless some similar products, in terms of basic construction can be found as can be seen in Fig. 4. Although the basic construction principles are similar, big differences are found in the 'optical' design. The Swedish products are designed rather simply in terms of appearance, but also from the technical point of view. For the Austrian and German market the product appearance seems to play a bigger role to attract costumers (Fig. 4).

This is somewhat curious because the heating systems in Germany and Austria are normally installed in a separated heating room in the cellar of the house, where the appearance should not be that important. The attitude might have changed due to the fact that these rooms are more and more actively used for leisure activities and it may be that women more often take part in the decision-making for buying the heating system, who are not solely interested in technical values.

In terms of comfort the Austria boilers are very user-friendly and provide almost the same comfort as gas or oil boilers. In contrast to Swedish boilers the passages and burner are often cleaned automatically by helical screws also serving as turbulators to improve the heat transfer to the heat distribution fluid. The ash from the combustion chamber is also removed without the help of the user and some manufacturers provide an inbuilt ash compressor that reduces the ash removal times from the boiler to a minimum.

Austrian boilers are mostly equipped with an aspirator for the air supply and a lambda sensor for optimal combustion and a modulation of the heating power. These systems reach high boiler efficiencies up to 94%. It is unlikely that Swedish boilers can only be adjusted for a fixed operation power. Some manufacturers provide predefined settings for a second or third operation point (e.g. winter/summer operation). In two-unit boilers the burner is not optimized for the operation in a standard boiler leading to efficiencies lower than 85% and higher emissions compared to Austrian boilers.

The more advanced technology and design of Austrian/German pellet heating systems is, of course, reflected in higher prices. A complete boiler in the range of 10 to 20 kW costs between 7000 and 10,000 Euros including tax, where the transport system between the pellet store and the boiler is often included in the price. For a similar Swedish system the customer has to pay between 4000 and 6000 Euros, including tax. A transport system is usually not included, but this does not significantly affect the price difference (Table 1).

In all three countries the number of pellet boilers is increasing. In Sweden the low price for pellets and presumably also the comparable cheap boilers is the driving force [22]. In Germany and Austria governmental incentives, the high comfort and the good image of environmental friendly technologies has encouraged the market for pellet heating [15].

3.2. Stoves

There are two main types of pellet stoves available, stand-alone pellet stoves and chimney integrated stoves. The only difference between these two types is that the

Table 1
Characteristics of typical Swedish and Austrian pellet boilers [6,31,40]

Property	Swedish boilers	Austrian boilers
Type	two unit boiler	integrated boiler
Power modulation	50%/100%	30–100%
Boiler efficiency[a]	78–85%	86–94%
Combustion air supply	blower	aspirator
Combustion control	no	no/lambda/speed controlled fan
Lighting	automatic	automatic
Air-passage cleaning	manual	automatic, optional
Cleaning burner	manual	automatic, optional
Ash removal from combustion chamber	manual	automatic, optional
Time interval ash removal from ash pan	weekly	2–8 times per year
CO emissions [mg/m^3]	260-650[b]	12–250[c]
Price	4000–6000 Euro	7000–10,000 Euro

[a] At nominal power.
[b] At nominal power with 10% O_2.
[c] At nominal power with 13% O_2.

latter is especially dimensioned to be placed in an open fireplace. The most common stove is the stand-alone stove.

Stand-alone stoves usually have an integrated pellet storage, which allows storage of a limited quantity of pellets, usually enough for 1 or 2 days. A few stoves are on the market which can be coupled with external pellet stores (e.g. EcoTec Tyr [20]).

Pellet stoves work using the same basic principles as pellet boilers. The pellets are combusted in an integrated burner, which is similar to the ones use in pellet boilers. Most pellets stoves use a fall channel from the integrated or external storage to feed the pellets to the burner pot. Through openings in the bottom of the pot the primary air and the hot air for the automatic lighting is supplied. The secondary air is usually preheated through the mantel of the pot and fed by many small openings of the mantle. The aspirator supplying the combustion air for the stove is placed below the burner. Sometimes an additional fan is used to improve the heat transfer from the stove to the ambient air. To simplify ash removal, the pellets are combusted on a manually or automatically operated moveable grate plate allowing the ashes to fall down in the ash container.

3.3. Types of pellet burners

Depending on how the pellets are fed into the burner three types of pellet burners can be distinguished (Fig. 6). These are:

- bottom fed burners;
- horizontally fed burners; and
- top fed burners.

The majority of the burners on the Swedish market work with the top feeding principle.

Burners designed by this principle are very frequently used in both pellet boilers and pellet stoves and have the advantage that the pellet store is always separated from the combustion zone and that way the danger of back burn from the furnace is very small [6]. This also prevents a long after-glow if the burner is turned off.

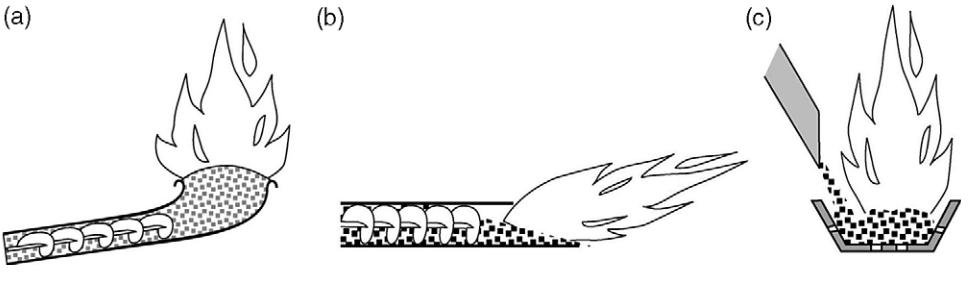


Fig. 6. Types of pellet burners by their feed principle: (a) bottom fed burner; (b) horizontally fed burner; (c) top fed burner [9].

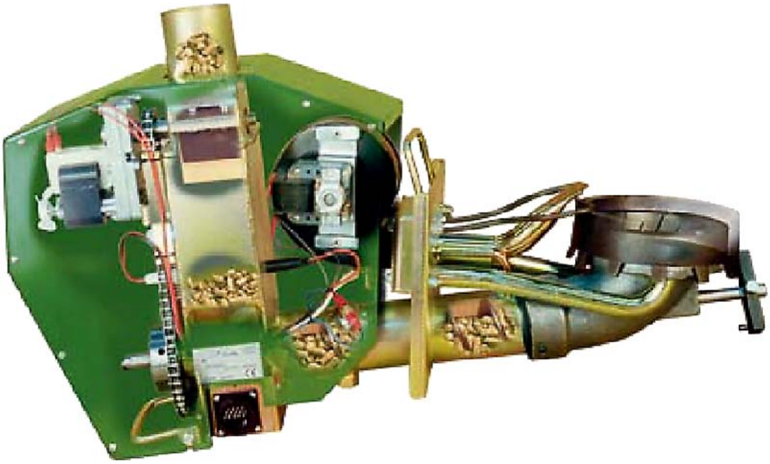


Fig. 7. Example of a bottom fed pellet burner, EcoTec AB.

Moreover, it ensures that an accurate dosing of pellets is conveyed from the top according to the current power demand. Disadvantageous is that the falling pellets have a negative impact on the firebed, resulting in an increased release of dust and unburned particles. It also causes unsteady combustion behavior [10]. More details about the top fed burner are describes in the section on ‘Stoves’. Bottom fed burners are originally designed for the use of wood chip boiler, but are also suitable for pellets (Fig. 7). A screw conveyor transports the pellets through the burner pipe and pushes them on the combustion disk, where the primary combustion (gasification) takes place. The primary air is supplied by the pellet supply or by openings in the burner head. The supply of the secondary air for the combustion of the released gases is placed on the burner disk or provided by air tubes above the disk. No separate ash removal construction is necessary. The ash is displaced by the pellets and falls over the edge of the disk down to the ash container or ash transport system. The combustion with this burner is very consistent but also has, due to the supply principle of the pellets, a long after-burning period. Additional safety measures are necessary to minimize the risk of back burning [10].

Horizontally fed burners are basically similar to bottom fed burners. The only difference is the form of the combustion bed and that for this type of burner additional ash removal is necessary.

Burner construction can also be distinguished by the way the flame leaves the burner. There are *horizontal flame* burners, where the flame is burning straight into the boiler and *upward flame* burners where the flame burns upwards [6]. Burners with a downward flame technology also exist [27].

3.4. Control techniques

The Swedish pellet heating units are usually on/off controlled by temperature settings. A modulation of the heating power is not possible, but some pellet burners offer a two step operation, maximum and half power for winter and summer use. For these steps the settings for air supply and pellet supply are fixed. The control possibilities are therefore somewhat limited. The initial adjustment of the burner by the installer has high significance for that reason. Wrong adjustment will lead to bad combustion, high emissions and low efficiency. For the same reason the maintenance of the flue gas passages is extremely important. Deposited ash and slag residues reduce the air supply with the same drastic results [14]. A few manufactures (e.g. Baxi) offer retrofit lambda regulation sets to solve these problems.

In almost all boilers a flame sensor is installed to monitor the combustion and the lighting of the pellets with hot air. More sensors might be installed to allow error diagnostics.

3.5. Safety

The major safety problem in pellet heating systems is the burn-back danger from the combustion chamber to the pellet store and the pellet conveyer. To prevent burn-back various measures can be applied. The simplest solution is the use of a top fed type of burner with a temperature controlled back flap in the falling shaft. Very common is also the use off cell-wheel locks (Fig. 8) in the pellet supply unit of bottom fed and horizontally fed burners. In a cell-wheel lock the turbine blades, transporting the pellets, prevent flames reaching the pellet supply because of their short distance to the housing.

Another decoupling can be achieved by using a falling shaft separating the conveyor screw from the storage and pellets burner. Another cell-wheel lock is sometimes placed at this position.

In some boilers a sprinkling system is used for putting out the flame when a defined temperature is exceeded.

Pellet boilers certified with the Swedish P-mark certificate [3], need to have at least two independent back-burn security measures between the storage and com-

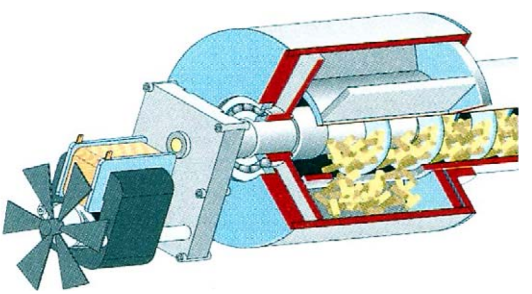


Fig. 8. Cell-wheel lock, [27].

bustion chambers. The connection pipes from the pellet store must be built from non-combustible materials. For boilers with an integrated pellet store and stoves there must be three independent back-burn measures. For integrated pellet stores with a volume larger than 40 dm^3 a sprinkling system is compulsory [3].

3.6. Maintenance

3.6.1. Cleaning and de-ashing

Pellet boilers require generally more maintenance compared to conventional boilers. The most common maintenance and cleaning work are:

- Refilling of pellets (especially if the storage is integrated in the boiler or a week-long store is used);
- Cleaning the burner from ashes and slag;
- Cleaning the flue gas passages;
- Ash removal from the ash container;
- Cleaning the window of stoves.

Highly automated pellet boilers often have electrically driven helical screws in the flue gas passage in order to remove ash and slag. At the same time, they serve as turbulators to improve the heat transfer by creating a turbulent air flow. Boilers with horizontal passages, often used for oil boilers, are not suitable for pellet boilers as flue ash and slag deposit much more easily, requiring shorter maintenance intervals.

Some burners are designed with an integrated ash removal and cleaning system which is manually or automatically driven, e.g. top fed burner Windhager [25].

Another time-consuming job is ash disposal, especially for Swedish pellet boilers, since for most systems the ash has to be removed every week [32]. In most Austrian boilers the ash is automatically removed from the combustion chamber by a conveying screw and compressed before it is stored in the ash container. The manufacturers of these systems claim that the ash needs to be removed only once to three times per year [25,26].

3.6.2. Emissions dependent on maintenance

Emission measurements on various pellets boiler and stoves have been carried at the Solar Energy Research Center (SERC) within the research project PESTO (http://emb.du.se/serc/serc.html). One of the test systems was a combination of a solar storage equipped with a immersed air to liquid heat exchanger for the coupling with pellets burner. The horizontal heat exchanger of the boiler requires regular cleaning from ash. In Fig. 9a the values for CO, O_2 and the flue gas temperature for one stop/start sequence is illustrated for a recently cleaned heat exchanger. Following the black line for CO the increased values during the start and the stopping of the burner can be observed. Fig. 9b shows a similar stop/start sequence for the system after being in use for 4 days' burning of 140 kg pellets. The carbon monoxide emission increase significantly during the combustion and exceed several times the limit value for CO of 2000 mg/m^3. The increased CO

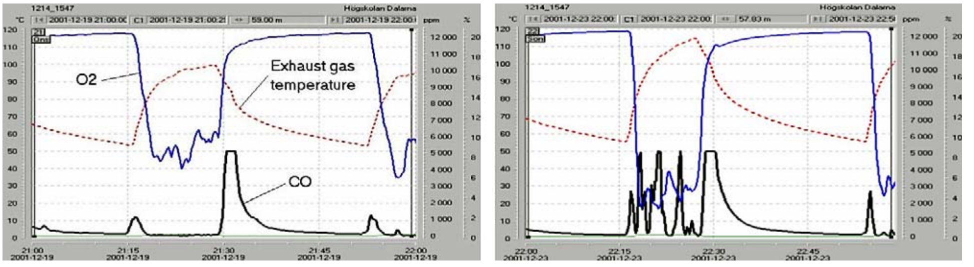


Fig. 9. Start/stop sequence of a pellets boiler (a) with a clean air to liquid heat exchanger; (b) after combustion of 140 kg pellets. CO content of the fluid gas in ppm (black solid line), O_2 content in % (grey solid line), and exhaust gas temperature (dotted red line) [14].

emission are due to an incomplete combustion caused by a reduced air supply. Ash and slag residues in the pipes of the heat exchanger reduce their effective diameter and lead to a smaller air draft [14].

The examples show that there is great potential for improvement for certain Swedish products on the market. The manufacturers and the research institutes in this field should use their knowledge and experience to further develop the existing products or to develop new products which will attract more customers for pellets in Sweden, and allow competition with other manufacturers in the European market.

3.7. Pellet transport systems and stores

In many cases the boiler will be placed separate from the store. To transport the pellets from the store, two main technologies are used:

- conveyor screws;
- suction systems.

Conveyor screws are used when the storage is located near the boiler. If larger distance have to be bridged, the use of a suction system is advisable, where the pellets are carried by the principle of a vacuum cleaner.

Integrated pellet stores are limited in their volume. To reduce the number of fillings required, external stores are offered in various designs. Often a reconstructed room is used to store the pellets. If a conveyor screw is used to transport the pellets to the boiler, the store needs to have a funnel shape to ensure that the pellets slide down to the bottom placed conveyor screw. Other solutions are stores made of dust-proof cloth or concrete-based storage, which are operated in most cases with suction systems.

If an oil heating system is replaced by a pellet heating system, the size of the pellet store need to be three to four times greater than for oil, depending on the bulk density of the pellets. For a house with a heat demand of 20,000 kWh, a pellet store volume of 6 to 8 m^3 is required if the store is to last for 1 year.

3.8. Chimney

Pellet stoves and boilers require a chimney to release exhaust gases safely to the atmosphere. The use of pellet heating units without a chimney or with a direct connection to the air through a wall is not allowed according to the Swedish regulations of the National Board of Housing, Building and Planning (Boverket). The latter is not explicitly declared but prohibited by the statement that exhaust gases have to be prevented from re-entering the building by the ventilation system or windows. Furthermore, the regulation specifies criteria of materials and dimensions for chimneys. Flue gas channels and tubes connected to the chimney must not have surface temperatures higher than 100 °C. There are no specifications for a minimum exhaust gas temperature from the boiler to prevent condensing in the chimney. The standard brick chimneys are of course not suitable for use with condensing boilers, a humidity-resistant chimney is required [4]. A European certificate is in preparation allowing the end user to identify suitable heating systems for the chimney (P. Johansson, Boverket, Karlskrona, personal communication).

4. Emission regulations

The extensive use of wood as a fuel for heating purposes in residential areas can lead to low air quality and health risks if the obsolete boilers are used or the heating units are inappropriately used or poorly maintained. Emission regulations are necessary to protect inhabitants from hazardous exhaust gases and dust and to encourage manufacturers to optimize their products for low emissions. Modern pellet boilers are characterized by lower emissions compared to log wood or wood chip boilers (see Fig. 10) and further improvements are possible.

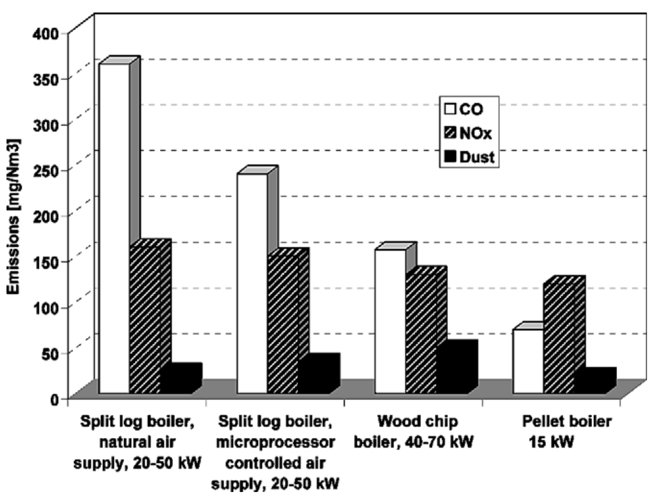


Fig. 10. Emissions for various types of wood heating boilers, [33].

Most relevant emissions from pellet boilers are carbon monoxide, unburnt hydrocarbons, nitrogen oxides and dust. The use of pellets boiler and pellets is liable to the compliance of the Swedish emission regulations given by The National Board of Housing, Building and Planning (Boverket) and the Swedish Standards Institute (SIS). Boverket recommends limit values for small-scale biomass combustion only, whereas SIS requires the compliance of the values given by the European Standard EN 303-5, which has since 1999 been applied as Swedish standard.

In Table 2, Swedish emission regulations are summarized together with the equivalent regulations in Germany. The official standards differ only slightly and the values given by the German Ministry of Economic Affairs and Technology are only recommendations. Nevertheless they are important for the costumer who wants to install a pellet system. If the boiler, burner or stove does not reach the given values, no subsidies will be given by the German Government. For small-scale pellet combustions units (3–50 kW) equipped with automatic pellet feeding, a subsidy of 55 Euro per kW is given by the German authorities [10].

The limit values for noxious emission given by EN 303-5 are classified for boilers according to boiler efficiency. In Table 2 only the limit values for boiler with class 3 efficiency are listed, which are the strictest values. Class 3 boilers must have minimum boiler efficiency between 67% (1 kW) and 77% (50 kW) [5]. Performance tests of 10 Swedish pellet burners (maximum 20 kW) carried out by the company Äfab in cooperation with the Swedish consumer agency (Konsumentverket) showed that all commercial devices reached efficiencies above 75% [6]. For the measurements the burners were coupled to a standard boiler, which allows the assumption that

Table 2
Official regulations and guidelines for emissions from small-scale wood combustion units [4,5,8,33]

Regulation	Supply	Nominal power (kW)	Limit value for emission (mg/m^3 dry flue gas with 10 vol-% O_2, 0 °C, 1013 mbar)		
			CO	OGC	Dust
EN 303-5 (valid since 1999)	manual	<50 kW	5000	150	150
	automatic	<50 kW	3000	100	150
Swedish Boverket	manual and automatic	<50 kW	2000	150[a]/250[b,c]	100
German Federal Ministry of Economics and Labour[c,d] (guideline)	manual and automatic	<15 kW	250[e]/500[f]	–	50
Bundes-Immissionsschutzgesetz – BimSchV[c,g]	manual and automatic	15–50 kW	4000	–	150

[a] For pellet boiler.
[b] For pellet heating stoves.
[c] Limit values are defined for 13 vol-% O_2 in the dry flue gas.
[d] Boiler efficiency has to be minimal 85%.
[e] Nominal load.
[f] Low load.
[g] No regulation for boiler/stoves smaller 15 kW.

the efficiency would be higher if the burners are coupled to a boiler designed for that specific burner.

For this reason and to simplify the comparison of limit values between the different standards, class 1 and class 2 boilers are not mentioned in Table 2.

In some countries such as Germany, Austria, Sweden, Great Britain and Switzerland variations from EN 303-5 are in use. The variations, usually stricter requirement of emissions, efficiency and safety, and their source are specified in the appendix of the standard [5]. In Sweden the stricter emission requirements can be found in the construction instructions from the Swedish National Board of Housing Building and Planning [4], whereas in Germany the "Verordnung zur Durchführung des Bundes-Imissionschutzgesetzes" [34] specifies the limit values for emissions.

As can been seen from Tables 2 and 3, different attempts to encourage the technical improvements of pellet boilers and stoves, in terms of reduction of noxious emissions are applied in Sweden and Germany.

Beside the official regulations, a number of customer-made standards and certificates exist. The Swedish National Testing and Research Institute (SP) tests boilers, burners and stoves according to their own test requirements, including emission measurements (Table 3). A product that passes all the tests and fulfils the emission limits will be awarded a test certificate, the so-called P-mark (http:\\www.sp.se).

Table 3
Emission limit values for automatically fed pellet heating devices given by relevant eco-labels and costumer made regulations [2,3,43–46]

Regulation	Power range kW	Operation power	Limit value for emission (mg/m^3 dry flue gas with 10 vol-% O_2, 0 °C, 1013 mbar)			
			CO	OGC	NOx	Dust
SP, Svensk provning-sanstalt P-mark (Sweden)	<50 kW	average	2000	75		–[a]/100[b]
Svan mark (Nordic countries)[c]	<100 kW	nominal and low load	1000[a]/ 1250[b,d]	70[a]/55[b]	–	70[a,d]/10[b,e] (20[b,f])
Blauer Engel[h] (Germany, 2003)	<15 kW	nominal load	100[a]/200[b]	5[a]/10[b]	150	30[b]/35[b]
		low load	300[a]/400[b]	5[a]/15[b]	–	–[g]
	15–50 kW	nominal load	100[a]/200[b]	5[a]/10[b]	150	30[a]/35[b]
		low load	250[a]/400[b]	5[a]/15[b]	–	–[g]
ECO-LABEL (EU)	not yet defined	not yet defined	not yet defined	not yet defined	not yet defined	not yet defined

[a] Pellet boilers.
[b] Pellet stoves.
[c] For automatically fed pellet heating systems.
[d] At nominal load.
[e] At average load.
[f] Maximal value for individual test.
[g] Value must be specified.
[h] Limit values are defined for 13 vol-% O_2 in the dry flue gas.

In Sweden, the SP requirements are setting the benchmark for emission and technical reliability. A pellet heating system with a P-mark certificate has a significant advantage on the market. The German Government encourages low emission and high efficient technology by direct financial assistance [7]. Both attempts promise further improved pellet combustion devices. Financial help for replacing old oil or wood boiler with modern pellet technology was also provided in Sweden within the framework of the local investment program (LIP) for environmentally friendly technologies. This program was completed in 2002. Meanwhile a new program called the local climate investment program (KLIMP) has been started containing similar incentives.

Further encouragement for high efficiency and low emission boilers and stoves are ecological labels. In the Nordic countries, the Svan-mark is a common label for environmentally friendly products. This label also specifies requirements for pellet boiler and stoves, but so far only one manufacturer has certified its pellet boilers (LIN-KA Maskinfabrik A/S, Denmark). According to SIS Miljömärkning AB, several manufacturers are in contact for a certification of their products (J. Ove Liljekvist, SIS Miljömärkning AB, Stockholm, personal communication). A similar label exists in Germany with the Blauer Engel-mark [35]. In 2003, requirements for a certification of pellet-wood, pellet heating systems with this label have been introduced by the German Federal Environmental Agency [36]. The first certified products are the pellets stoves of the company Wodtke [23]. On the European level a label named Eco-Label [37] with a flower logo has been developed based on criteria specified by the European Union Eco-labeling Board (EUEB) [38]. So far no criteria for pellet heating systems exist. In Table 3 the limit values for emission from these Eco-labels are summarized. The values are exclusively valid for automatically fed pellet heating systems. For manually fed heating units, the requirements are usually less stringent.

5. Quality standards for wood pellets

A consistent high quality of wood pellets in terms of chemical and mechanical properties is a basic requirement for good combustion and a reliable functioning of pellet heating systems. Standards for pellets in Europe so far exist in Switzerland [16], Norway [42], Sweden [19], Germany [17] and Austria [18]. The specifications of the last three standards are compared in this paper. The Swiss pellet standard is equivalent to the German DIN standard.

The chemical properties of pellets significantly influence the quality of the combustion, emissions and efficiency. The lower the water content in the pellets the better is their heating value. The ash content should be as low as possible to avoid slag in the burner plate and the flue gas passages. Additives might be used to improve the pressing of the raw material. Such a binding agent can be natural substances, such as corn or maize starch, but also chemical glues, which should not be used but are tolerated by the Swedish standard.

A high density ensures a high heating value and steady combustion behavior. A varying pellet density causes problems especially for boilers with a fixed air supply and volumetric pellet dosing [6].

For the transport of the pellets from the store to the combustion chamber the pellet dimensions play a major role. It has turned out that a diameter of about 6 mm is optimal for most transport systems on the market in Austria and Germany [10]. In Sweden a diameter of 8 mm is most common [21]. An important quality parameter is also the abrasion value which indicates the mechanical stability of the pellets. The Austrian standard requires determination of the abrasion values by a so-called lingo-test [15], where the pellets are exposed to mechanical stress and the resulting amount of small wood particles is measured. In the Swedish standard, the fraction of small particles is determined directly in the delivery from the manufacturer.

The actual requirements of the Swedish standards compared to the standards in Germany and Austria can be seen from Table 4. The strictest regulations can be found in Austria within the official Ö-Norm and within the German DIN plus norm which is not obligatory for the pellet manufacturers. The DIN plus norm is more a certificate used as a marketing instrument to promote high quality pellets. The Swedish pellet standard divides the pellet qualities into three subgroups: class 1 with the strictest requirement mainly for domestic use to class 3 for district heating plants with the lowest requirements. Though class 1 pellets are the strictest values in Sweden they still exceed the limit values for the Ö-Norm and DIN plus. The German DIN norm also includes an additional analysis for heavy metals.

Table 4
Pellet standards in Sweden, Austria and Germany

Pellet standard	Unit	Sweden, SS 187120			Austria	Germany	
Parameter		Class 1	Class 2	Class 3	Ö-Norm M7135	DIN 51731	DIN plus
Diameter (d)	mm	≤25	≤25	≤25	4–10	4–10	4–10
Length	mm	≤4×d	≤5×d	≤6×d	≤5×d	≤50	≤5×d
Density	kg/dm^3	≥0.6[a]	≥0.5[a]	≥0.5[a]	≥1.12	≥1.0-1.4	≥1.12
Water content	%	≤10	≤10	≤12	≤10	≤12	≤10
Abrasion/small particles	%	≤0.8[b]	≤1.5[b]	≤1.5[b]	≤2	–	≤2.3
Ash content	%	≤0.7	≤1.5	<1.5	≤0.5	≤1.5	≤0.5
Upper caloric value	MJ/kg	≥16.9	≥16.9	≥15.1	≥18	15.5–19.5	≥18
Sulphur content	% weight	≤0.08	≤0.08	–[c]	≤0.04	≤0.08	≤0.04
Nitrogen content	% weight	–[c]	–[c]	–[c]	≤0.3	≤0.3	≤0.3
Chlor content	% weight	≤0.02	≤0.02	–[c]	≤0.02	≤0.03	≤0.02
Additives	%	–[d]	–[d]	–[d]	2	–	2

[a] Bulk density.
[b] Particle in weight % <3 mm.
[c] Amount must be specified.
[d] Type and amount must be specified.

Within the continuing European standardization process, it can be expected that the German and Austrian standard will become the benchmark for a new European standard.

Recently a new certificate has been introduced by the German Pellet Association called PVD-Norm. It implements a coding system that should prevent a blending with low quality products between the production and the delivery. The retraceability to the manufacturer should be ensured by adding pellets with a coding of its origin. Moreover four unannounced inspections of the manufacturers per year are included. This new label certifies the boiler manufacturer, as well as pellets and pellet manufacturers [11]. Certification criteria are:

- high efficiency;
- low emissions;
- internal research and development;
- fast service.

6. Summary

The state of the art of pellet heating systems shows significant differences comparing systems from Sweden and Austria. Although the basic combustion principles are the same, the systems available on the market can be easily distinguished. Swedish pellet boilers are often two component devices: the burner is often a separate unit that can be combined with standard boilers which are also usable, for instance, for oil boilers. Swedish systems can be defined as half automatic working systems. The pellets supply is automated but not controllable in terms of modulation of the combustion power. The combustion and automatic lighting is monitored, but the air supply cannot be regulated. In contrast the Austrian boilers are fully automatic allowing a modulating operation, and often automatic ash removal which ensures high comfort, making them in terms of operation and user-friendliness almost equivalent to conventional boilers. The sophisticated technology has its price: Austrian boilers are on average 50% more expensive than Swedish boilers of equivalent rating.

A large potential for improvement can be seen for the Swedish pellet heating systems. This is partly due to the concept of combining pellet burners with standard boiler which are often optimized for use with oil boilers. Integrated systems would simplify the optimization of the interplay between burner and boiler. Combustion control with regulation of air and pellet supply could improve the thermal performance significantly and reduce noxious emissions. The maintenance requirements are rather larger compared to conventional boilers. Longer maintenance intervals could help to make this technology more interesting for a larger range of clients. The unattractive optical appearance and the two unit design of Swedish pellet boilers might be a handicap for the manufacturers if they try to penetrate the large market in Germany and even on the domestic market, because many single family houses do not have a separate heating room.

In both countries a great deal of development work is still necessary concerning compactness and system integration. But some manufacturers have already presented promising solutions.

However, the existing technology is working reliably and most products are tested and certified. Several thousand units have already been installed with considerable satisfaction from the customers [22].

The technology and design of pellet stoves sold in Sweden, Austria and Germany differ only marginally. Manufacturers, such as Wodke, are present on all markets and set the trend. The combustion technology in pellet stoves is somewhat similar to that used in boilers.

Although pellet heating technology is rather young, there are already a number of regulations for pellet boilers and stoves. The most important regulations concern emissions, safety techniques and installation in homes.

Standards for the fuel (pellets) have been introduced in five European countries, where the strictest official standard is applied in Austria. A common European standard is under development and can be expected in the near future.

Beside the official regulations, a number of custom-made certificates and labels have been introduced, helping the customer to find high quality products.

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